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An Ambient Intelligent System for Improving Therapy Adherence of Chronic Patients

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Abstract. The amount of chronic diseases is increasing in Western societies due to the ageing of the population. This tendency is accompanied by the increased medical costs in the health care sector. The costs of constant personal supervising of chronic patients aimed at the improvement of therapy adherence are particularly high. Moreover, chronic disease therapy imposes a burden on everyday life of chronic patients and their psychological well-being as it requires strict regimen and self-control. In this context Ambient Intelligence techniques have an explicit potential in both reducing the medical costs in the health care sector and improving the well-being of chronic patients. Our approach is to adopt Ambient Persuasion technology to solve the problem of therapy adherence of chronic patients. It will be realized by means of an adaptive agent-based ambient support system which uses cognitive models of patient's behaviour to influence their adherence.

Keywords: chronic disease management, ambient intelligence, therapy adherence, ambient persuasion.

1 Introduction

The number of persons with chronic diseases is rapidly growing because of the aging of the population and changing lifestyle and habits [Nolte 2008, WHR 2002]. This tendency is accompanied by the increased medical costs in the health care sector.Treatment of chronic diseases often consists of a combination of lifestyle advices and medication. Many patients experience difficulties in following treatment recommendations [WHO, 2003]. Adherence to these recommendations is often far from optimal, especially in patients with chronic diseases. According to [Claxton et al, 2001], therapy adherence of patients with chronic diseases ranges between 70-80%. As a result of this widespread adherence problem, substantial numbers of patients do not get the maximum benefit of their medical treatment - with poor health outcomes, lower quality of life and increased health care costs as a result [Burke, 2001; Einarson, 1993]. The impact of poor adherence is felt even more as the burden of patients with chronic diseases grows worldwide [Sabaté, 2003]. Patients with chronic diseases require long-term adherence.

Adherence can be improved by patient counselling as is common in disease management programs. However, personal counselling is expensive, especially given the fact that chronic patients will often require treatment for the rest of their life. Permanent personal counselling is therefore often not realistic. However, adherence is not a static property and as such, it is likely to decline when counselling is ended. In [Lee, 2006] a study is described which shows how adherence increases from 61.1% to 95.5% during a 6-month care program, but that it declined to 66.5% six months after the end of the program.
Ambient Intelligence support systems have a potential to fulfil the role of a personal counsellor and to substitute or extend a human counsellor in many aspects. For example, a personal electronic counsellor can give a feedback to a patient about his therapy adherence, lifestyle, can remind of forgotten medicine intake, provide with the necessary health information or motivate and encourage a person to go on with the positive behaviours. In the frame of Human-Computer interaction this support system can be seen as a part of Ambient Persuasion technologies that aim at influencing individual's attitudes and behaviours [Fogg 2003].
In the next section of the present paper we will describe the theoretical basis of the proposed ambient intelligent application, in Section 3 the general description of the application is given. Finally, section 4 provides with some conclusions concerning the proposed application and suggestions for future research.

2 Theoretical Background

2.1 Cognitive Modelling

Cognitive modelling forms the basis of the present Ambient Persuasion application. Cognitive modelling is a method to explain the structure and the processes of the human mind by building (executable) models of these processes [Detje et al, 2003]. This involves the formalization of existing theories and the translation into an executable format. The experimental results of such models can offer new insights to the disciplines that formulated the theories. For example, when psychologists establish a theory that describes a specific reasoning pattern that humans use in certain circumstances, the cognitive modeller can make a (computer) model of that theory. If, subsequently, this model predicts roughly the behaviour described by the theory, however with some small deviations, the psychologists can use these predictions to create a refined (and hopefully more realistic) theory. In addition, the models can be used to build computer programs that adapt their behaviour based on the expected situation of the user.
In order to influence patient's behaviour in the present context, the system should be able to detect the undesired behaviour either directly or indirectly. Direct observation of person's actions provides information on the actual behaviour, but the information about internal cognitive and emotional states of a person is not directly observable. However, this information can be deduced from other types of observable behaviour or the information that is directly communicated by a patient. Cognitive Modelling approach

allows reasoning about internal states of a particular person and adjusting a support strategy accordingly.

In the proposed application, a model of the adherence behaviour and behaviour change of patients will be build following the cognitive modelling approach.

2.2 Adherence Behaviour

The formal model of adherence in this study will be based on existing behavioural and educational theories on adherence. Behaviour depends on stimuli or cues that elicit certain responses, and on the rewards that reinforce behaviour. These are the main and best known original principles of behaviour theory [Leventhal 1987]. In a meta review that included over 1300 original studies Sluijs et al found (2006) that interventions based on incentives and reminders can be successful in improving patients' adherence. Behavioural adherence interventions focus directly on patients' non-adherence behaviour. In this project, the motivational messages and reminders act as cues or stimuli that elicit certain responses, and the feedback about the achieved results (w.r.t. personal goals) via the website and the mobile phone acts as reward that reinforces the desired behaviour. Bandura incorporated principles from social learning theories in behavioural theory, for example modelling and vicarious learning (learning by watching, listening or reading). He also added the concept of self-efficacy, the confidence in one's capacity to perform the desired behaviour [Bandura 1977].

Educational theories include three theoretical mainstreams [Leventhal 1987 in Sluijs 2006]. The first one is the communication perspective, which focuses on the idea that the patient should be informed adequately. Adequate not only implies that patients understand and retain the message but also that they accept the information on the treatment, regimen and the benefits of adherence behaviour. Our study is interactive and patients will be informed in a tailored way and will also receive advice that better fits their own private situation, which may improve acceptance of the message. The second mainstream educational theory is the cognitive perspective that focuses on cost/benefit analysis as a motivating factor to act (Rational belief model, Health Belief model, Theory of Reasoned Action or Planned Behaviour). These models assume that health related behaviour is determined by perceived health threats and the benefits of health behaviour. The well known basic dimensions of the Health Belief Model are: the perceived probability and severity of the threat on the one hand and the perceived benefits of health behaviour and the barriers to such behaviour on the other hand. Weighing the benefits and barriers and the consequences of various behaviours provides the motivation for the actions to be taken. Such weighing is not based on objective rational computations, but on the individual's own subjective perceptions of the pros and cons. Our study collects up to date information about the patients' behaviour, both with respect to his personal life style change goals as his medication usage, and provides it in an orderly manner directly to the patient. This helps the patient to make a cost-benefit analysis based upon her/his own individual information rather than on based upon information from general populations. This can be seen as empowerment of the patient to manage his own disease treatment.

Finally self regulative models emphasize the patients themselves as active problem solvers [Leventhal 1997]. Patients try to close the gap between the current (health) status and a goal. In self-regulative models behaviour is considerably influenced by patients' subjective experiences and emotions. Behaviour depends on:

- the patient's perceptions of the current status and the goal;
- the patient's plans for changing the current status to reach the goal (coping);
- the patient's appraisal of the progress in reaching the goal.

If goals are not reached, patients may change their perceptions (the labelling of the status) and/or their way of coping. Patients' ways of coping depend on cognitive considerations, for example the perceived identity of health threats and their labelling of the symptoms and potential causes. Coping may be triggered by internal stimuli (for example symptoms) or external stimuli such as a website.

A recently developed model, focusing on adherence uses the full stages of change model [Johnson et al, 2006]. This model includes elements of the theories described above and adds – among other things – the idea that changes occur in a nonlinear way. Moreover, the idea is that most people recycle to previous stages several times before behaviour change is achieved (frequently observed in smoking cessation). Feedback is an essential part of this model; in this study feedback information will be communicated using personalized messages via the phone or the personal website, and, if too urgent or too specific, by a health professional (GP, pharmacist or assistant, depending on the imbedding in larger program). In this case the health professional will be notified and informed by the system as well. The "stages of change" model has previously been used in a study to increase patients' adherence to lipid lowering treatment. The authors found that patients who were treated according to this model, were more likely to be adherent at 12 (55.3% versus 40%, $p<0.05$), and at 18-months (56% versus 37.8%, $p<0.01$) [Johnson, 2006].

3 Improvement of Adherence Behaviour

A recent meta-review on interventions in the field of adherence concluded that these should be simple and relatively easy to implement [Sluijs et al 2006]. These results are in line with the persuasive technologies described by Fogg in [Fogg 2006]. An example of such a simple application is an innovative reminding method developed a few years ago, which made use of SMS-messages that were sent to a patient a few minutes before each scheduled moment of intake. A study among patients with type 2 diabetes showed that this method has immediate positive results [Chuang 2003]. However, the SMS-messages became routine; after about 6 months the effects diminished. RTMEMS (Real Time Medication Event Monitoring) has been developed as an improvement on this SMS-alert system: it only sends a SMS-message in case the patient indeed forgets to take the medication. RTMEMS has been tested in pilot projects which typically include between 5 and 200 patients, and focus on areas such as HIV, tuberculosis (TB), hepatitis C, hypertension, leukemia a.o. In a pilot project of the Dept. of Health of the Western Cape Province in South Africa with 150 TB patients the medication compliance of the patients

averaged over 90% and the cure rate exceeded 94%. This compared well with the average cure rate in this Province which stands at 76%.

Reminder systems, however, only solve part of the adherence problem. First of all, they only focus on medication intake, and not on life style aspects of a therapy. Moreover, the existing reminder systems are built upon the assumption that the reason for non compliance to therapy is "forgetting". However, non-adherence is often related to motivation problems and a lack of knowledge about the reasons for the treatment and the consequences of non-adherence on the longer term.

It is obvious that a smarter intervention approach should exploit this broader view on adherence. This approach should take persuasive technologies into consideration that are broader than simple reminder systems. Helping patients to effectively control their disease requires an intervention that takes both the practical and the psychological aspects of behaviour change into account. Such an intervention could benefit from an 'understanding' of both the patient's non-adherence behaviour and the psychological steps required to change this behaviour. Understanding can be achieved by building a model that relates the attitudes, intentions and beliefs of the patient to his actions and the development of his disease. By reasoning over the model using the actual observations of a patient as input (i.e. the compliance to his own goals and plans, his medication intake data), one could possibly determine some of the beliefs of a patient and provide him with focused educational information, motivational messages, and specific reminders. Such a 'self-management support system' should help the patient to both to assess his own situation and help him to adhere to the therapy, ultimately resulting in a higher quality of life.

In this project, we will develop an intelligent online self-monitoring and self-support system, with the aim of improving adherence to therapy, both with respect to lifestyle changes and medication intake. This system can be used within disease management programs as a new element or as long-term follow-up to support retaining the effects of personal counselling. The core of the system consists of a mobile phone and web application that gives a patient personalized advice, focused information, appropriate reminders and motivational messages. Computer-tailored health education has shown to be an effective way to change health behaviour [Kroeze et al, 2006]. The personal advice is generated by a computer, using a computational model of patient behaviour (change).

This model will be built using psychological literature and domain expert knowledge. The computer will use this model to reason about the current psychological state of the patient. The input for this reasoning process consists of medication intake data and reports about the personal goals of a patient and his achievements.

For generating the information we will use 'Semantic Web' technology, which means that information will be described with meta-data and a computer readable representation of the meaning of information. This is then used to specify how information for patients should be composed from different pieces of text.

The medication intake data will be collected using an electronic medicine box, which automatically registers the fact that medication has been taken and then stores this data in a central database. For the self-reports, we will develop an application that will run on modern mobile phones. This program will allow patients to answer a few questions about

their goals and achievements in a simple way. The elements of the model and the system are meant to be generally applicable to chronic diseases. The ultimate goal is that the system provides an improved adherence to therapy (both to medication intake and life style changes), eventually resulting in a reduction in the risk of developing late-stage complications.

4 Conclusions

The present paper describes an example of application of Ambient Persuasion in health-care domain. Based on the Cognitive Modelling approach, the presented application should be able to improve therapy adherence behaviour of chronic patients. The given system seems to utilize two prominent strategies of persuasive technologies, as described in [Fogg 2006], namely persistence and simplicity. The system allows for a constant monitoring of patient's behaviour and constant support at appropriate times. At the same time, this system is based on conventional mobile phones application, web site and electronic pillbox technologies. It does not require any complicated human-computer interactions that may burden patient's memory or psychological well-being by annoying interference with common everyday activities. Within the project, we hope to answer the question how the different psychological theories can contribute to mobile and web technology that persuades patients to improve their therapy adherence.

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